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RESEARCH MEMORANDUM

for the

U. S. Air Force

CONCLUDING REPORT OF FREE-SPINNING, TUMBLING, AND RECOVERY CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE

COORD. NO. AF-199

By James S. Bowman, Jr.

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Langley Field, Va.

CLASSIFIED DOCUMENT

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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CONCLUDING REPORT OF FREE-SPINNING, TUMBLING, AND RECOVERY CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE

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SUMMARY

An investigation has been completed in the Langley 20-foot free-spinning tunnel on a 1/18-scale model of the Ryan X-13 airplane to determine its spin, recovery, and tumbling characteristics, and to determine the minimum altitude from which a belly landing could be made in case of power failure in hovering flight.

Model spin tests were conducted with and without simulated engine rotation. Tests without simulated engine rotation indicated two types of spins: one, a slightly oscillatory flat spin; and the other, a violently oscillatory spin. Tests with simulated engine rotation indicated that spins to the left were fast rotating and steep and those to the right were slow rotating and flat. The optimum technique for recovery is reversal of the rudder to against the spin and simultaneous movement of the ailerons to full with the spin followed by movement of the elevators to neutral after the spin rotation ceases.

Tumbling tests made on the model indicated that although the Ryan X-13 airplane will not tumble in the ordinary sense (end-over-end pitching motion), it may instead tend to enter a wild gyrating motion.

Tests made to simulate power failure in hovering flight by dropping the model indicated that the model entered what appeared to be a right spin. An attempt should be made to stop this motion immediately by moving the rudder to oppose the rotation (left pedal), moving the ailerons to with the spin (stick right), and moving the stick forward after the spin rotation ceases to obtain flying speed for pullout. The minimum altitude required for a belly landing in case of power failure in hovering flight was indicated to be about 4,200 feet.

INTRODUCTION

In accordance with a request by the U. S. Air Force, an investigation has been conducted to determine the spin, recovery, and tumbling characteristics of a 1/18-scale model of the Ryan X-13 airplane and also to determine the minimum altitude required for a belly landing in case of power failure in hovering flight. Test results previously completed to determine the size of parachute required for emergency spin recovery and to determine the spin and recovery characteristics without simulated engine angular momentum are presented in references 1 and 2, respectively. The present report presents the concluding results in this investigation and includes the spin, recovery, and tumbling characteristics for the model with and without simulated engine angular momentum. Also included in this report are the results obtained to determine the minimum altitude that would be required for a belly landing after power failure in hovering flight.

All tests were conducted for the normal weight-full-fuel loading (with hook instead of landing gear) at a center-of-gravity location of 32.5 percent mean aerodynamic chord.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations of model mass characteristics occurring during tests, and a general comparison between available model and full-scale airplane results.

SYMBOLS

b — wing span, ft

S — wing area, sq ft

$\bar{c}$ — mean aerodynamic chord, ft

$x/\bar{c}$ — ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ — ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below reference line)

m — mass of airplane, slugs

I_X, I_Y, I_Z — moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2

$\frac{I_X - I_Y}{mb^2}$ — inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ — inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ — inertia pitching-moment parameter

ρ — air density, slugs/cu ft

μ — relative density of airplane, $\frac{m}{\rho Sb}$

α — angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ — angle between span axis and horizontal, deg

V — full-scale true rate of descent, ft/sec

Ω — full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

The 1/18-scale model of the Ryan X-13 airplane was built at the Langley Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model is shown in figure 1, and a photograph of the model as tested is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). The loading conditions possible on the X-13 airplane and the loading tested on the model are presented in table II.

The tumbling tests were made by launching the model with both positive and negative initial rotation with elevators in the up, neutral, and down positions and with rudder and ailerons neutral. These tests were made for both zero and idling engine speeds.

The drop tests conducted to simulate power failure in hovering flight were made outside in favorable weather conditions in which the surface wind velocities were about 10 knots or less. No control movement was attempted during the drop, and, therefore, the controls remained fixed throughout any one control configuration tested. The drop tests were conducted by hoisting the model 165 feet by a pulley arrangement to a boom located at the top of a water tank. The model was then allowed to drop from rest in a nose-up hovering attitude by pulling a pin releasing the model. A large net was installed near the ground to catch the model.

All spin and drop tests were conducted with and without simulated engine angular momentum for full (8,000 rpm) and idle (4,000 rpm) engine speeds. The tumble tests were conducted for conditions simulating both engine off and idling.

The angular momentum of the rotating parts (counterclockwise as viewed from rear) of the full-scale Rolls-Royce Avon R.A. 14 jet engine was simulated by rotating a flywheel with a small direct-current motor powered by small silver-cell batteries. The flywheel was located in the model so that the axis of the angular momentum was parallel to the longitudinal axis of the airplane.

A remote-control mechanism was installed in the model to actuate the controls for spin-recovery attempts in the spin tunnel. Sufficient hinge moments were exerted on the controls for recovery attempts to reverse them fully and rapidly.

Longitudinal and lateral control are obtained from one control known as an elevon. In determining the deflection of the elevon control, motions resulting from longitudinal and lateral deflections of the stick are additive. For convenience, elevon motions are discussed herein in terms of elevator and aileron movements. The maximum control deflections (measured perpendicular to the hinge line) used were as follows:

Rudder, deg	25 right, 25 left
Ailerons, deg	17.5 up, 17.5 down
Elevators, deg	22.5 up, 2.5 down

RESULTS AND DISCUSSION

The results of the spin and recovery tests are presented in charts 1 to 5 and for the tumbling tests in table III. The results of the drop tests are presented in table IV.

Spin Tests

Power off.- Results of the spin tests conducted without simulated rotation of the engine parts are presented in chart 1 and indicate that, for this condition, spins ranging from slightly oscillatory to violently oscillatory were possible. At times, the model oscillated out of the spin and went into a wild gyrating motion. These results were similar to those reported in reference 2 for a more forward center-of-gravity position in that satisfactory recovery from the developed spin by reversal of the rudder alone could not be obtained. Aileron deflections against the spin (stick left in a right spin) were adverse to recovery, whereas moving the ailerons to with the spin in conjunction with reversal of the rudder resulted in satisfactory recoveries. However, after recovery the model often entered a spin in the opposite direction; therefore, the pilot should neutralize rudder and ailerons on the airplane immediately after recovery from a spin.

Power on.- Spin tests conducted with the simulated idle and full engine speeds are presented in charts 2 to 5. Spin-test results were consistent with reference 3 in that, for spins in which the flywheel rotation and spin direction were in the same sense (left spins), the model generally spun steeper and rotated faster, and, for spins in which the flywheel rotation and spin direction were in the opposite sense, the model spun flatter and rotated slower than for spins in which no engine rotation was simulated. Computations indicate that the pilot may be subjected to transverse (forward and rearward) accelerations tending to push him forward from his seat (against his belt) and toward the nose of the airplane as high as seven times that of gravity for the spin with high rates of rotation.

Test results indicate that for the X-13 airplane, the engine angular momentum will have a very large effect on the spin and recovery characteristics. The spins conducted on the model simulating left spins on the airplane with power on (engine rotation and spin direction in the same sense) were steeper than spins without simulated engine rotation and were slightly to violently oscillatory (charts 2 and 3). The optimum control movement for recovery was the same as for power-off spins, that is, rudder deflected to against the spin and simultaneous movement of the ailerons to with the spin with the stick full back followed by movement of the elevators to neutral after the spin rotation ceases. After recovery, the model invariably started turning in the opposite direction, but instead of developing a spin in the opposite direction, as was generally the case for power-off spins, the model oftentimes went into a wild gyrating motion. This motion, which may be difficult for the pilot to terminate, consisted of a rolling motion with simultaneous yawing and pitching. (See fig. 3.)

Model results indicated that right spins on the airplane (engine rotation and spin direction in the opposite sense) would be very difficult to obtain (charts 4 and 5). A developed spin on the model could be obtained only when ailerons were full against the spin with simulated idle engine rotation. It was indicated that recoveries from this spin by rudder reversal and simultaneous movement of ailerons to with the spin would be rapid unless the stick was forward longitudinally, but the model quickly went into a wild gyrating motion after spin recovery. Although the model could not be made to spin unless the ailerons were full against the spin, when attempts were made to launch the model into the spin at other control configurations, the model went into the wild gyrating motion previously discussed. From these tests it appeared that when the model at a high angle of attack was yawed in a sense opposite to the engine rotation, it was very inclined to enter the gyrating motion.

The angular momentum of the simulated rotating jet engine was very large because of the large engine installed in the relatively small X-13 airplane, and the resulting gyroscopic moment was probably the primary factor leading to the wild gyrating motion of the model. All spins on the X-13 airplane should be avoided, but in the event a spin develops with power on, it is recommended that the power be cut and the engine rotation allowed to decrease as much as possible before recovery is attempted by full rudder reversal and simultaneous movement of the ailerons to full with the spin. This procedure should minimize the chances of entering the wild gyrating motion.

Tumbling Tests

The tumbling-test results are presented in table III. The test results indicate that, although the airplane will not tumble in the ordinary sense (end-over-end pitching motion), it will instead tend to enter the wild gyrating motion previously mentioned.

The tendency for the model to enter the wild gyrating motion was more pronounced when the model was launched with negative initial rotation (nose down) than with positive initial rotation (nose up) with simulated engine rotation, apparently because the resulting gyroscopic yawing moment due to the nose-down pitching velocity yawed the model to the right, in a direction of opposite sense to the engine rotation.

Drop Tests

Some representative drop-test results are presented in table IV and typical motion-picture film strips of the tests are shown in figures 3 and 4.

The model test results indicate that, at the beginning of the drop when the engine is rotating at almost full speed, the airplane will drop tail down at first and then will nose over to or past the horizontal (figs. 3 and 4) at a rate for which the maximum rate of pitch was about 130° per second. The nose of the model generally tended to pitch forward and down (negative pitching). The resulting gyroscopic yawing moment of the simulated rotating engine due to the nose-down pitching velocity yawed the model to the right, and the model then entered what appeared to be a right spin. According to test results, approximately 6.5 seconds from flame-out would be required for the X-13 airplane to enter this motion which appeared to be a right spin. The engine rotation by this time on the full-scale airplane would only be about 2,000 rpm (fig. 5) and, therefore, the resulting motion or spin may be considered to be with no engine rotation. An attempt should be made on the airplane to stop this motion immediately by moving the rudder to oppose the rotation (left pedal), moving the ailerons to with the spin (stick right) and, then, after the spin rotation stops, moving the stick forward to obtain flying speed for pullout.

In some cases the nose of the model initally pitched back and down (positive pitching). The resulting gyroscopic yawing moment of the simulated rotating engine in this case due to the positive pitching velocity yawed the model in a clockwise direction as viewed from above, which is the same direction as for the case in which the nose of the model initially pitches negatively. The model in some cases rolled as it pitched positively and was in the erect position by the time the horizontal position was obtained. The model, therefore, ended in the same attitude and spin direction as when the initial pitching direction was negative. However, sometimes the model pitched without rolling. In this case the model pitched positively about 270° and then back to the vertical (nose-down) position and entered a dive.

Based on model test results, the altitude loss of the airplane from the time of flame-out to the time the spin was entered would be about 900 feet. This distance was calculated by assuming gravity acting on a freely falling body for the time it took the model to enter the spin. To recover from this spin and enter a glide required another 800 feet, which was based on the time for the model to recover from a spin in the spin tunnel at the rate of descent during recovery with flywheel-off condition. The distance required to obtain a horizontal trim flight attitude after recovery from the spin was not computed for the X-13 model, but, based on a similar configuration of reference 4, an assumption of 2,500 feet was made for the X-13 airplane. Therefore, the minimum altitude considered safe after flame-out should be approximately 4,200 feet.

SUMMARY OF RESULTS

Based on the results of tests of a 1/18-scale model of the Ryan X-13 airplane, the following conclusions are made for the airplane at an altitude of 25,000 feet in regard to the spin, recovery, and tumbling characteristics and in regard to the drop characteristics from power failure in hovering flight:

1. Two types of spins may be possible on the airplane, one a slightly oscillatory spin and the other a violently oscillatory spin.

2. The gyroscopic moments of the rotating jet engine parts will have a very large effect on the spinning characteristics. The spins to the left will be very fast and steeper and to the right will be very slow and flatter than spins with power off.

3. Aileron deflections against the spin should be avoided during spins.

4. The optimum control technique for recovery is reversal of the rudder to full against the spin and simultaneous movement of the ailerons to full with the spin followed by moving the elevators to neutral after the spin rotation ceases. The airplane may very quickly enter another spin in the opposite direction if the engine is off. Caution should be exercised to avoid entering another spin by neutralizing all controls immediately after recovery.

5. All spins should be avoided. If a spin should develop, the power should be cut immediately and the engine speed allowed to decrease as much as possible before recovery is attempted. The airplane may enter a wild gyrating motion if recovery is attempted with the engine rotating as much as or more than idle speed.

6. The airplane will not tumble but may enter a wild gyrating motion.

7. Recovery from the wild gyrating motion is doubtful.

8. The airplane, when falling as a result of power failure in hovering flight, will have a strong tendency to enter a right spin as a result of the gyroscopic yawing moment of the jet engine. The spin should be stopped immediately by the recovery technique previously mentioned and after the spin rotation ceases, the stick should be moved forward to obtain flying speed for pullout.

9. The minimum altitude required for a belly landing in case of power failure in hovering flight is indicated to be about 4,200 feet.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 25, 1957.

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APPENDIX

MODEL TESTING TECHNIQUE AND PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 5 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising airstream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 5.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 6 to 8). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full-up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin, the direction depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved for recovery until the spin rotation ceases. Recovery characteristics of a model are generally considered to be satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. A recovery of 10 or more turns is indicated as ∞. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	±1
ϕ, deg	±1
V, percent	±5
Ω, percent	±2
Turns for recovery obtained from motion-picture records	$\pm\frac{1}{4}$
Turns for recovery obtained visually	$\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of ±1°.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight, mass distribution, and the simulated angular momentum of the X-13 model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 1 high
Center-of-gravity location, percent $\bar{c}$	0 to 1 forward
Angular momentum, percent	10 high to 10 low
Moments of inertia:	
I_X, percent	5 high to 14 high
I_Y, percent	6 high to 8 high
I_Z, percent	7 low

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 9 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that, for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 9 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, although the higher rate of descent was found to be generally associated with the smaller angle of attack regardless of whether it was for the model or the airplane.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE RYAN X-13 AIRPLANE AS SIMULATED ON 1/18-SCALE SPIN MODEL

Overall length, ft	23.445
Wing:	
Span, ft	21.000
Area, sq ft	191.002
Sweep at leading edge, deg	60
Airfoil section, root chord	NACA 65A008
Mean aerodynamic chord (measured in wing chord plane), in.	145.49
Leading-edge mean aerodynamic chord rearward of theoretical leading edge of wing (measured in wing chord plane), ft	6.06
Incidence (measured between wing chord plane and water line), root, deg	4
Dihedral, deg	0
Elevons:	
Total area, rearward of hinge line, sq ft	22.095
Hinge line in percent of local chord:	
Root, percent	15
Tip, percent	15
Span, ft	6.135
Vertical tail:	
Total area, sq ft	47.205
Rudder, sq ft	7.065
Span, ft	9.150
Airfoil section	NACA 65A012

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE RYAN X-13 AIRPLANE AND FOR THE LOADING TESTED ON THE MODEL

[Values given are full-scale; moments of inertia are given about center of gravity.]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude, 25,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values											
Normal weight - full fuel with wheels	6,958	0.321	-0.077	22.65	50.57	1,728	4,326	5,109	-273×10^{-4}	-82×10^{-4}	355×10^{-4}
Normal weight - full fuel with hook	6,696	.325	-.088	21.81	48.70	1,543	4,042	4,833	-272	-86	359
Landing weight - 25 percent fuel with wheels	5,908	.323	-.047	19.19	42.85	1,255	4,138	4,748	-357	-76	433
Landing weight - 25 percent fuel with hook	5,646	.332	-.063	18.35	40.97	1,108	3,903	4,482	-362	-75	437
Minimum weight - 5 percent fuel with wheels	5,628	.324	-.042	18.35	40.97	1,158	4,117	4,652	-383	-70	453
Minimum weight - 5 percent fuel with hook	5,366	.328	-.055	17.40	38.87	982	3,820	4,354	-388	-73	461
Model values											
Normal weight - full fuel with hook	6,747	0.320	-0.058	22.02	49.17	1,614	4,291	4,499	-289×10^{-4}	-22×10^{-4}	311×10^{-4}

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TABLE III.- TUMBLING CHARACTERISTICS OF 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE

[Rudder and ailerons neutral, elevators deflected as indicated; center-of-gravity location, 32.5 percent $\bar{c}$.]

Loading	Configuration	Speed and direction of simulated engine rotation	Method of launching	Behavior of model		
				Stick full back	Stick neutral	Stick full forward
Normal weight - full fuel with hook	Clean	Zero	Positive initial rotation	(a)	(a), (b)	(a), (b), (c)
		Zero	Negative initial rotation	(b), (d)	(b), (d)	(c), (d)
		Idle (Counterclockwise viewed from rear)	Positive initial rotation	(d)	(c), (d)	(c), (d)
		Idle (Counterclockwise viewed from rear)	Negative initial rotation	(b), (d)	(b), (d)	(b)

[a] Stopped tumbling, entered spinning motion to left.
[b] Stopped tumbling, entered wild gyrating motion.
[c] Stopped tumbling, entered roll about the X-axis.
[d] Stopped tumbling, entered glide.

[redacted]

TABLE IV.- CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13

AIRPLANE WHEN DROPPED FROM HOVERING FLIGHT ATTITUDE

[Data are presented in terms of full-scale time and for a full-scale drop distance of 2,900 feet; results presented are representative of those obtained.]

Drop number	Control settings			Speed and direction of simulated engine rotation	Remarks
	Rudder	Ailerons	Elevator		
1	25° right	Neutral	10° up	Full (Counterclockwise viewed from rear)	Initial pitch direction negative. Dropped about 5.9 seconds before model started yawing alternately to the right and left until hit net.
2	Neutral	Neutral	10° up	Idle (Clockwise viewed from rear)	Initial pitch direction negative. Dropped about 5.5 seconds before model entered a left spin (opposite direction to flywheel rotation). Model made $2\frac{1}{2}$ turns in spin before hit net. (Drop shown in fig. 4.)
3	25° right	Neutral	10° up	Idle (Counterclockwise viewed from rear)	Initial pitch direction negative. Dropped about 7.3 seconds before model flattened out and started rotating to the right. After model made about $\frac{1}{2}$ turn to right, rotation stopped; model then fell for about 2.3 seconds in a trim attitude before it started rotating to right again.
4	25° right	Neutral	10° up	Idle (Counterclockwise viewed from rear)	Initial pitch direction negative. Dropped about 6.5 seconds before model entered a right spin. Model spun about one turn and then pitched up and entered a wild gyrating motion. Flywheel rotation had stopped by time model hit net. (Drop shown in fig. 3.)
5	25° right	Neutral	10° up	Zero	Initial pitch direction negative. Dropped about 5.5 seconds before model entered a right spin. After model spun for about one turn, it stopped rotating and entered a low angle-of-attack trim attitude with oscillation in yaw.
6	25° right	Neutral	10° up	Zero	Initial pitch direction negative. Dropped about 5.9 seconds before model entered a right spin. Spun about two turns before model hit net. Spin was fairly steady for first turn, then became oscillatory.

[redacted]

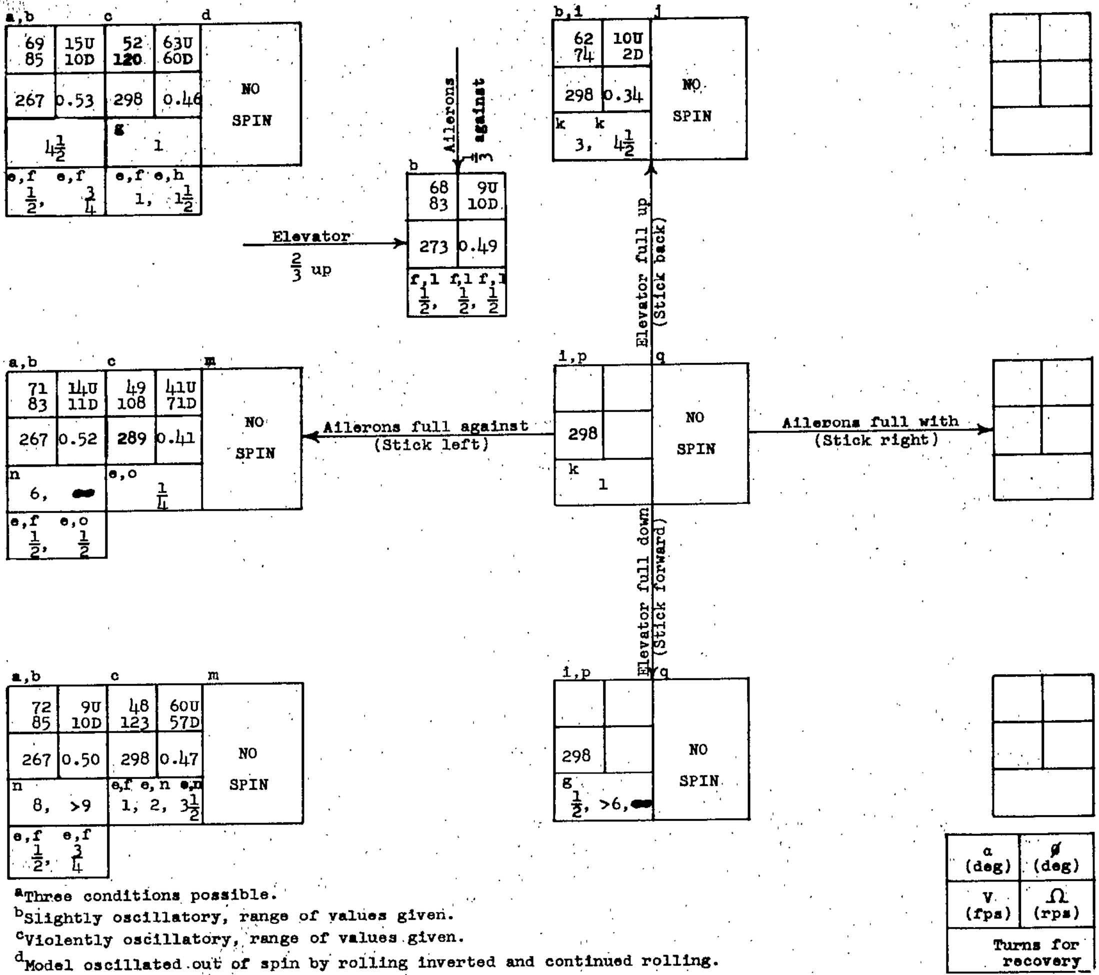
[redacted]

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction		Loading (see table II)
X-13	Erect	Right		Normal weight, full fuel, with hook
			Center-of-gravity position 32.5 percent $\bar{c}$	Altitude 25,000 ft

Model values converted to full scale   U-inner wing up   D-inner wing down



[a]Three conditions possible.
[b]Slightly oscillatory, range of values given.
[c]Violently oscillatory, range of values given.
[d]Model oscillated out of spin by rolling inverted and continued rolling.
[e]Recovery attempted by deflecting the rudder to full against the spin and simultaneously moving the ailerons to full with the spin.
[f]After recovery, model started rotating in opposite direction.
[g]After recovery, model pitched inverted and then rolled into an erect glide.
[h]Upon recovery model rolled inverted and continued to roll about the X axis.
[i]Two conditions possible.
[j]Entered a glide.
[k]Recovered in a glide.
[l]Recovery attempted by deflecting the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin.
[m]Entered a wild gyration type of motion.
[n]After recovery, model pitched inverted, then rolled erect, and continued to roll about the X axis.
[o]Recovered in an aileron roll.
[p]Violently oscillatory for short duration (15-20 turns) then oscillated out of spin.
[q]Model pitched inverted then back to erect position and may continue spinning.

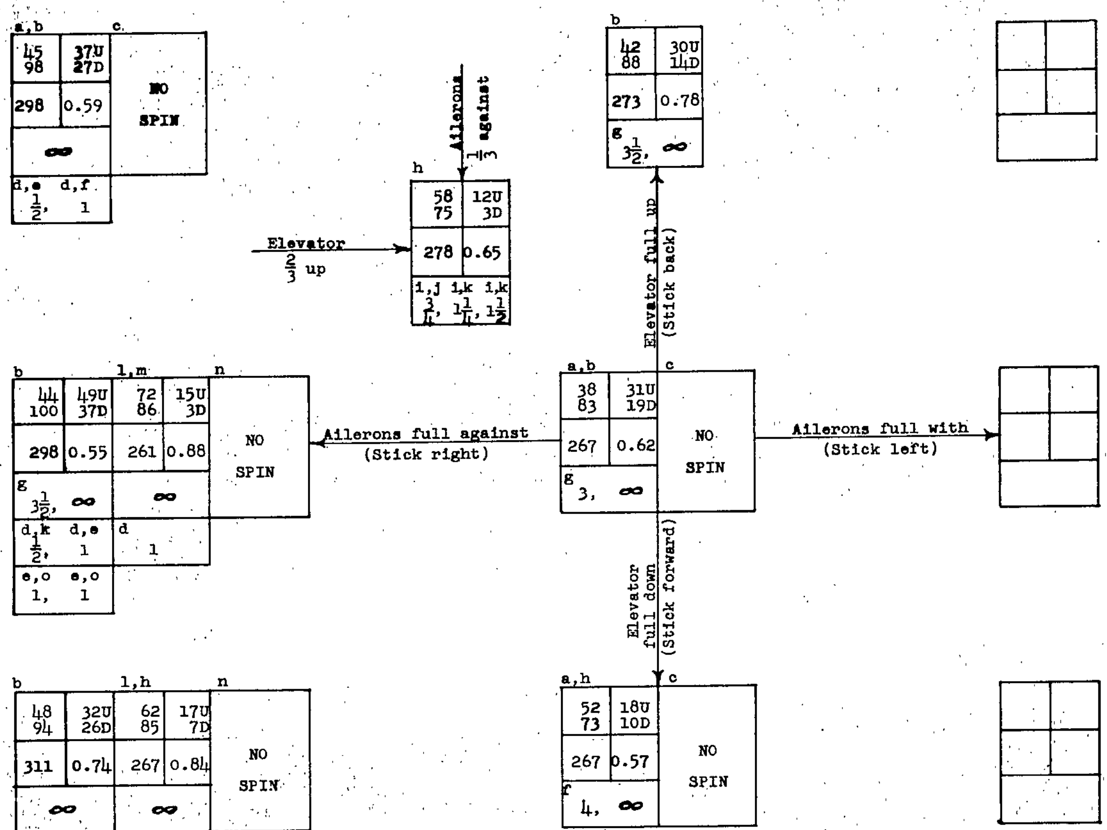
[redacted]

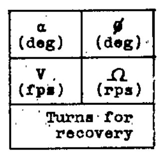
CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane X-13	Attitude Erect	Direction Left spin simulated	Loading (see table II) Normal weight, full fuel, with hook	Angular momentum for idle engine speed simulated (Engine rotation is counter clockwise as viewed from rear)
		Altitude 25,000 ft	Center-of-gravity position 32.5 percent $\bar{c}$	

Model values converted to full scale   U - inner wing up   D - inner wing down





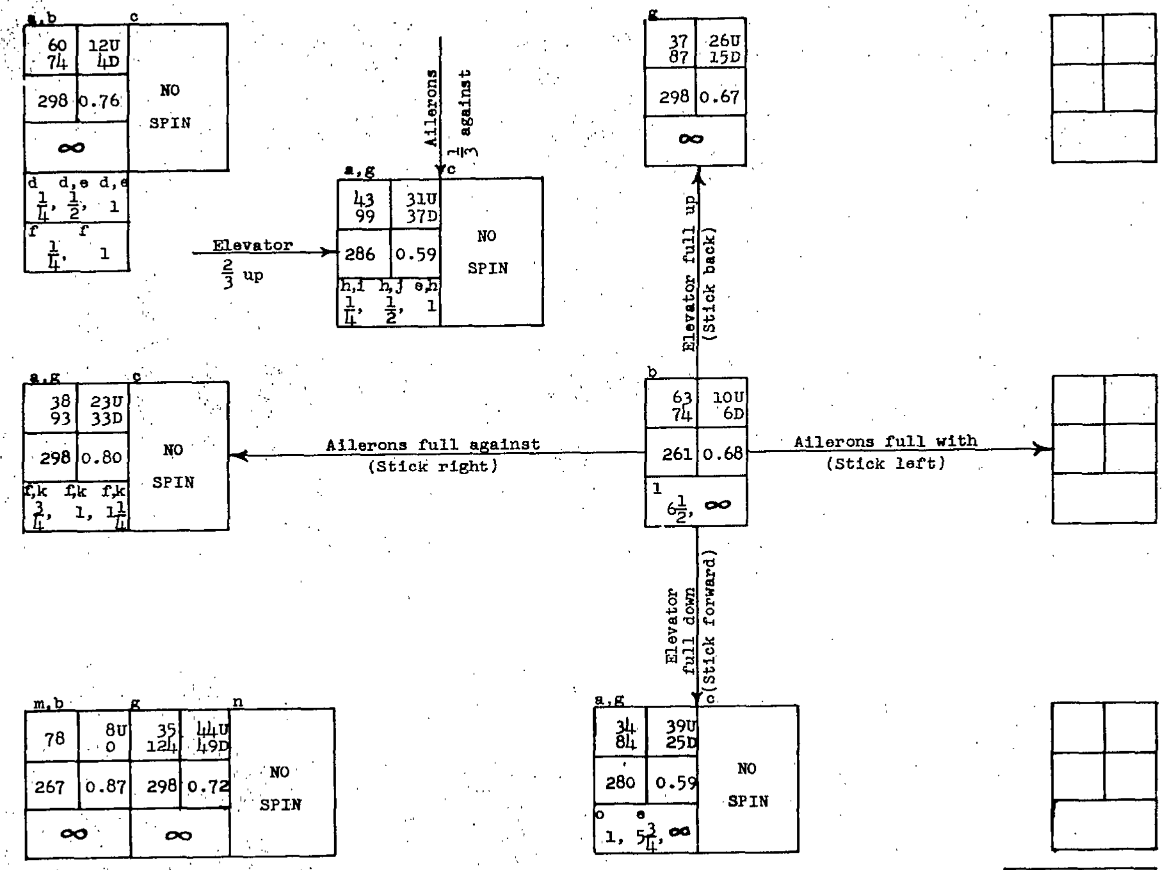
[a] Two conditions possible.
[b] Violently oscillatory; range of values given.
[c] Model entered a glide.
[d] Recovery attempted by deflecting the rudder to full against the spin and simultaneously moving the ailerons to $\frac{1}{2}$ with the spin.
[e] Model recovered in an aileron roll.
[f] Model recovered in a glide then started turning in opposite direction. Model then may pitch inverted and roll erect and inverted again.
[g] Model recovered in a glide.
[h] Very oscillatory, range of values given.
[i] Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and simultaneously moving the ailerons to $\frac{2}{3}$ with the spin.
[j] After recovery model started turning in opposite direction.
[k] Upon recovery, model entered a wild gyrating motion.
[l] Three conditions possible.
[m] Slightly oscillatory, range of values given.
[n] Oscillated out of spin by pitching inverted and then started rolling about X axis.
[o] Recovery attempted by deflecting only the ailerons to full with the spin.

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction	Loading (see table II)	Angular momentum for full engine speed simulated. (Engine rotation is counterclockwise as viewed from rear.)
X-13	Erect	Left spin simulated	Normal weight, full fuel, with hook	
		Altitude	Center-of-gravity position	
		25,000 ft	32.5 percent $\bar{c}$	

Model values converted to full scale U-inner wing up D-inner wing down



α (deg)	ø (deg)
V (fps)	Ω (rps)
Turns for recovery	

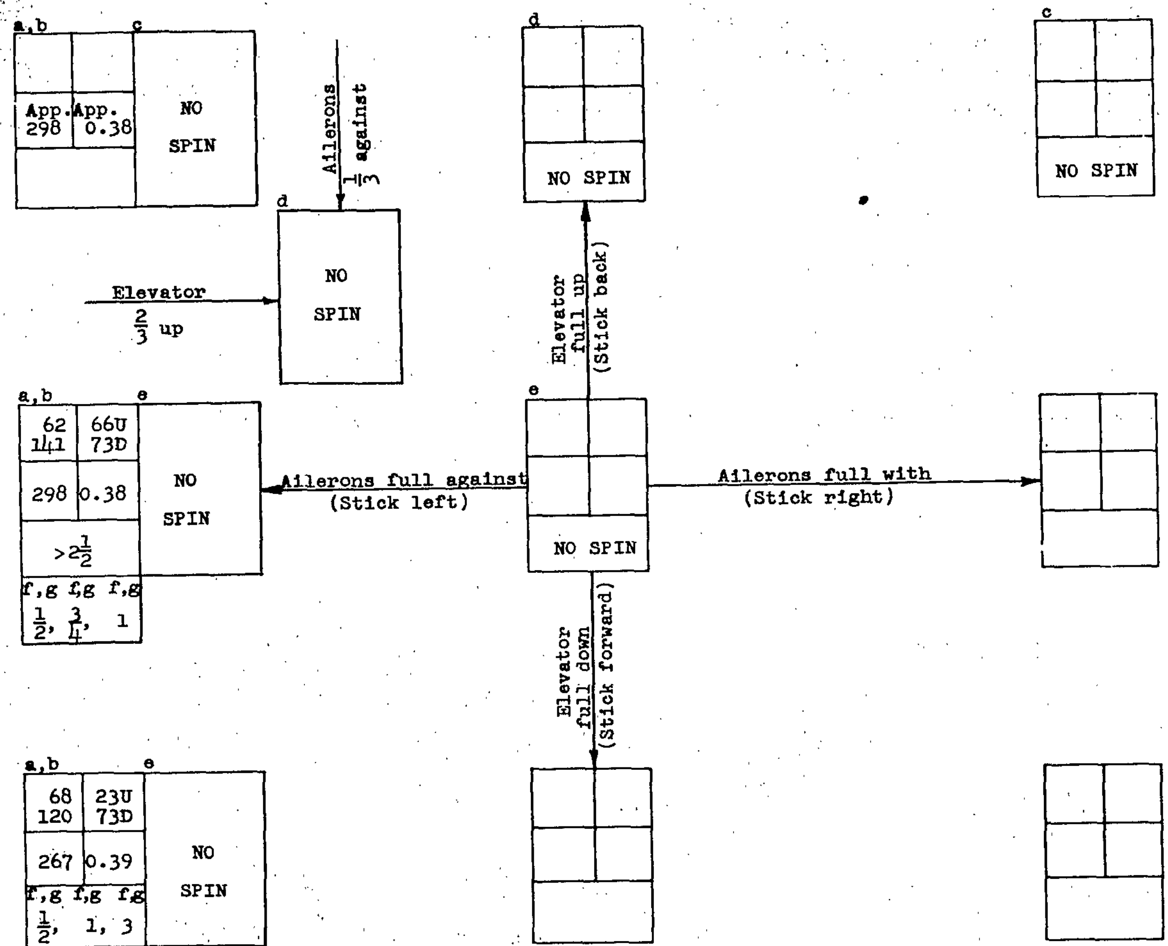
[a]Two conditions possible.
[b]Slightly oscillatory, range or average value given.
[c]Model entered a glide.
[d]Recovery attempted by deflecting the rudder to full against the spin and simultaneously moving the ailerons to full with the spin.
[e]Model recovered in a glide.
[f]Recovery attempted by deflecting the rudder to full against the spin and simultaneously moving the ailerons to $\frac{1}{2}$ with the spin.
[g]Violently oscillatory, range of values given.
[h]Recovery attempted by deflecting the rudder to $\frac{2}{3}$ against the spin and simultaneously moving the ailerons to $\frac{2}{3}$ with the spin.
[i]Upon recovery, model went into a wild gyrating motion.
[j]After recovery, model started spinning in opposite direction and then rolled inverted.
[k]Model recovered in an aileron roll.
[l]Model recovered in a glide and then started turning in the same direction.
[m]Three conditions possible.
[n]Model oscillated out of the spin by pitching inverted and then rolled about the X axis.
[o]Model recovered in a vertical dive and rolled about the X axis.

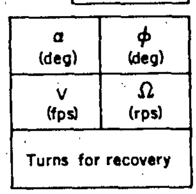
CHART 4.—SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Direction	Loading (see table II)	Angular momentum for idle engine speed simulated. (Engine rotation is counter-clockwise as viewed from rear.)
X-13	Erect	Right spin simulated	Normal weight, full fuel, with hook	
Slats	Flaps	Altitude	Center-of-gravity position	
		25,000 ft	32.5 percent $\bar{c}$	

Model values converted to full scale   U–inner wing up   D–inner wing down





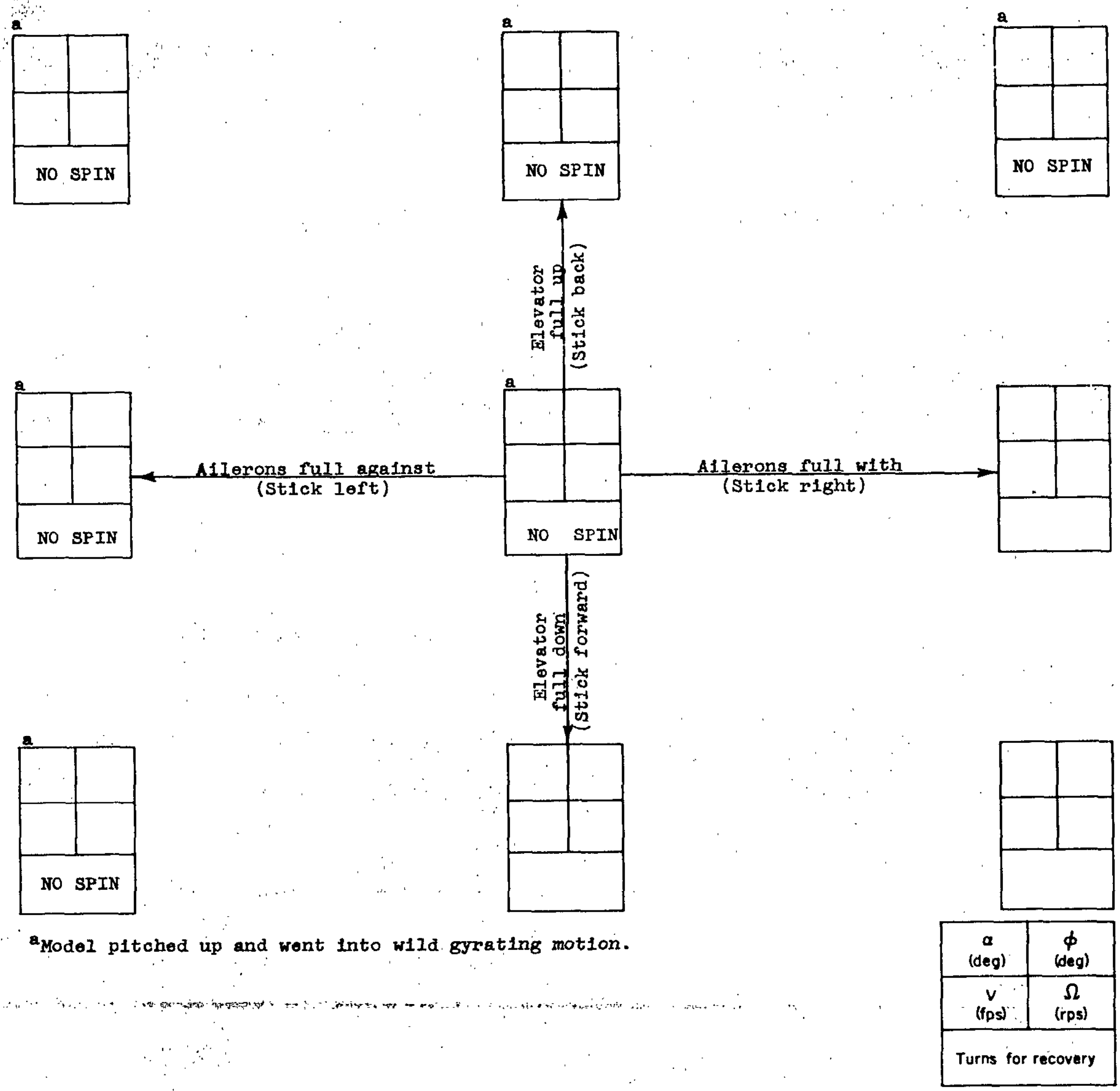
[a]Two conditions possible.
[b]Violently oscillatory for short duration (about 10 turns) then model rolled inverted.
[c]Model rolled inverted for about two turns then back erect.
[d]Model entered a wild gyrating motion.
[e]Model either entered a wild gyrating motion or rolled inverted.
[f]Recovery attempted by deflecting the rudder to full against the spin and simultaneously moving the ailerons to full with the spin.
[g]Upon recovery model want into a wild gyrating motion.

CHART 5.—SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

Airplane	Attitude	Direction	Loading (see table II)	Angular momentum for full engine speed simulated. (Engine rotation is counter clockwise as viewed from rear.)
X-13	Erect	Right spin simulated	Normal weight, full fuel, with hook	
Slats	Flaps	Altitude	Center-of-gravity position	
		25,000 ft.	32.5 percent $\bar{c}$	

Model values converted to full scale

U–inner wing up D–inner wing down



[a]Model pitched up and went into wild gyrating motion.

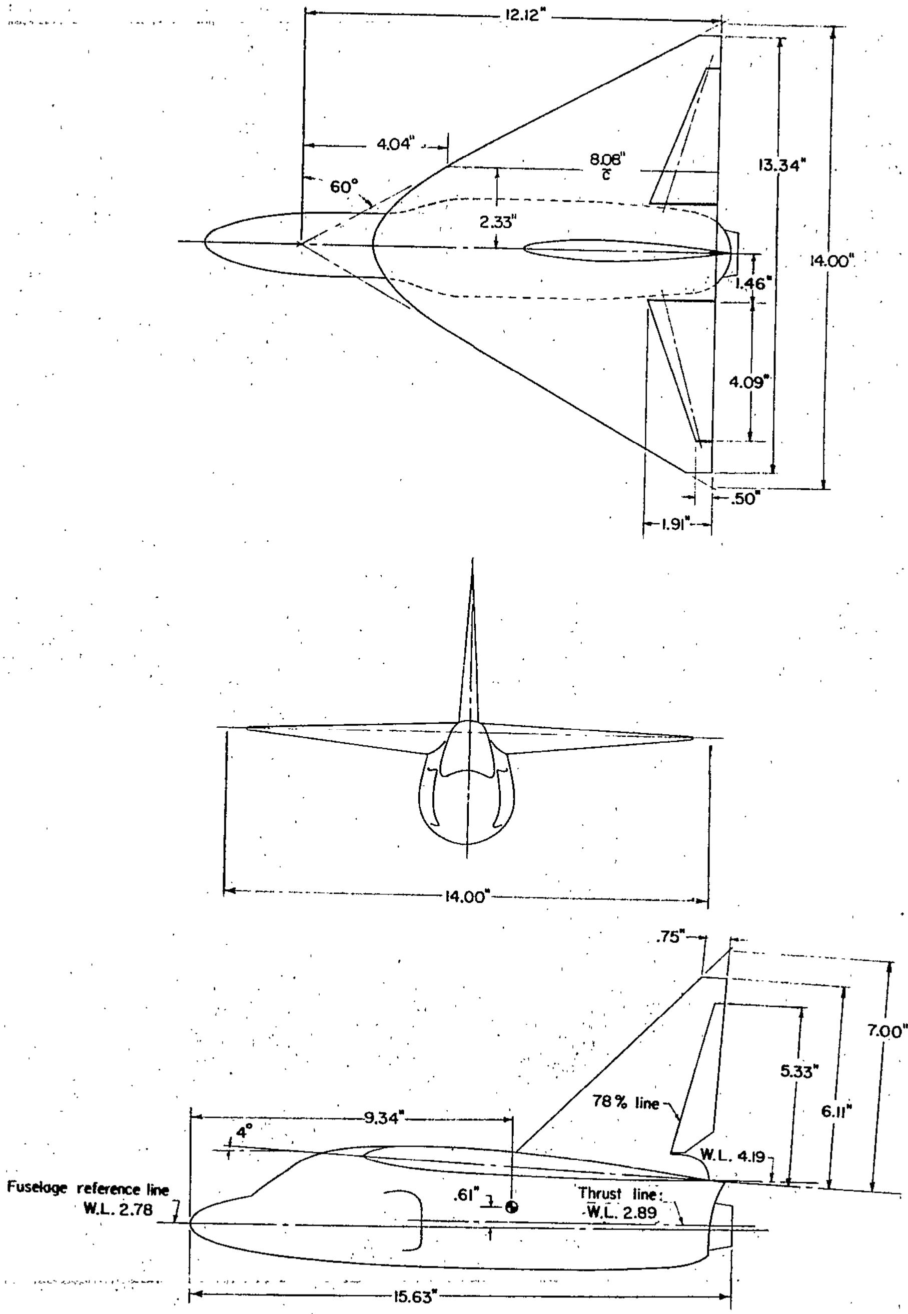
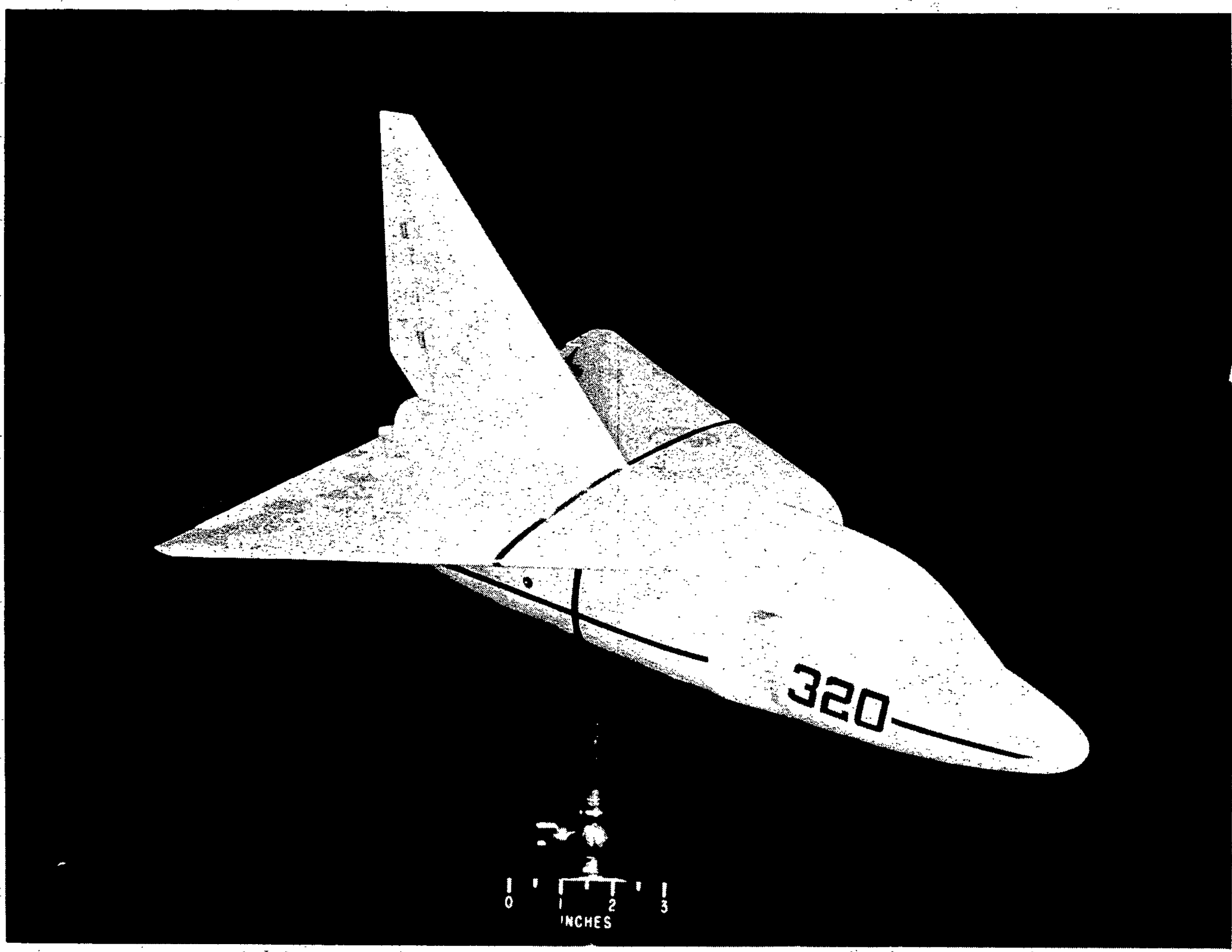
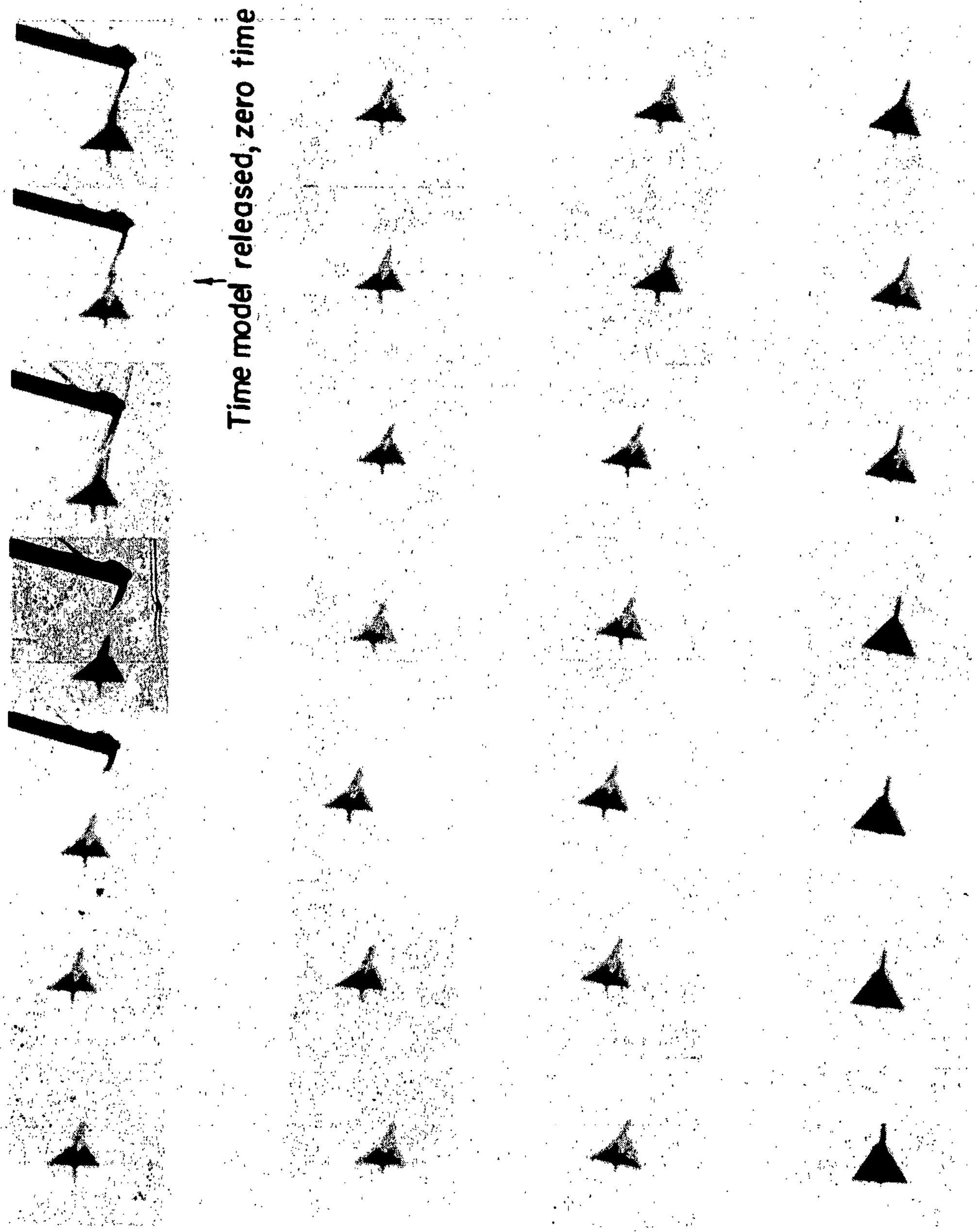


Figure 1.- Three-view drawing of a 1/18-scale model of the Ryan X-13 as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is 29.5 percent mean aerodynamic chord.



L-86735

Figure 2.- Photograph of the Ryan X-13 airplane model as tested in the Langley 20-foot free-spinning tunnel.



L-57-1559

Figure 3.- Film showing motion of a 1/18-scale model of the Ryan X-13 airplane after being dropped from a hovering flight attitude. Film was taken at 64 frames per second. (Idle engine speed simulated with rotation of flywheel counterclockwise from rear.)

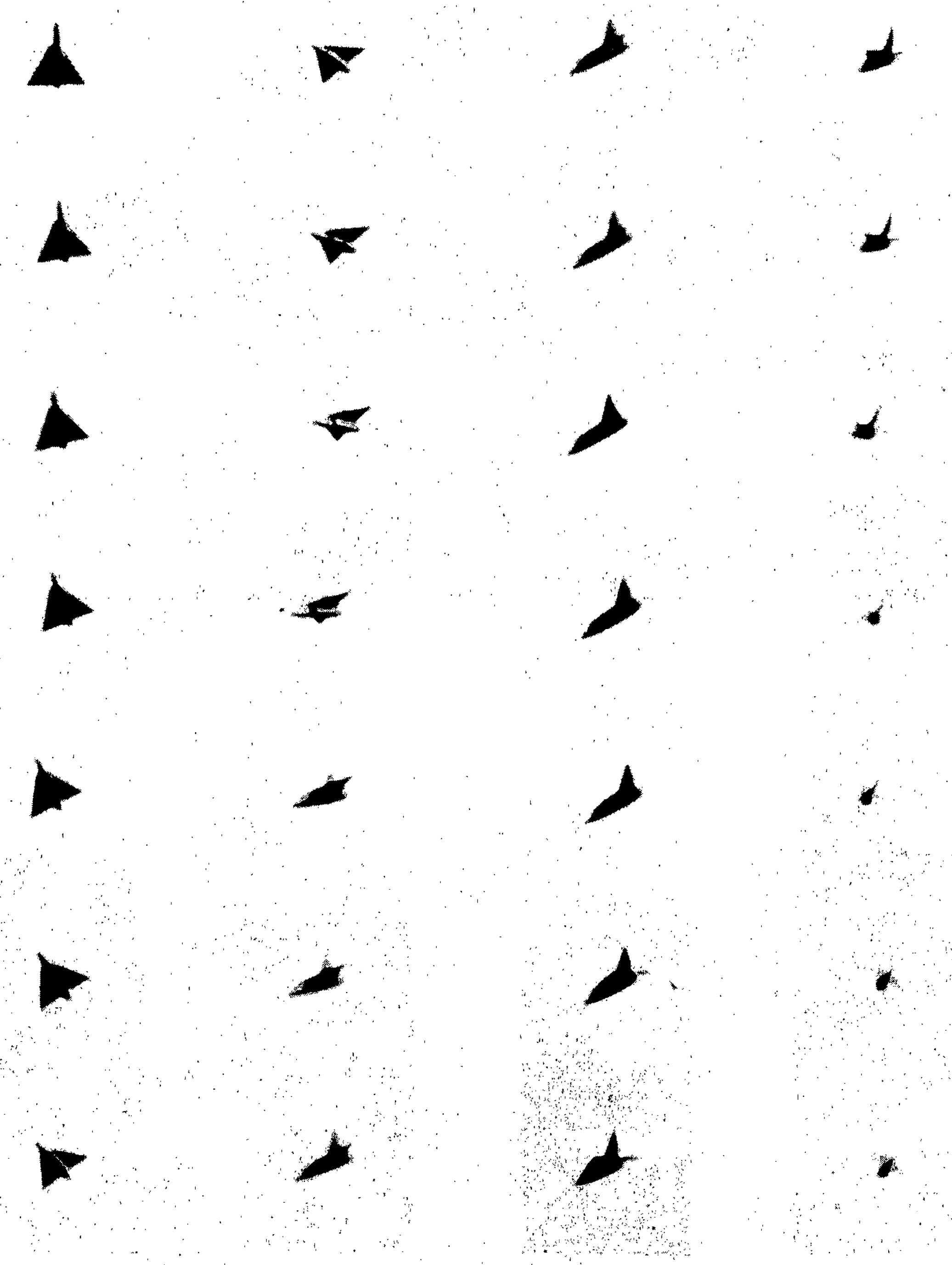


Figure 3.- Continued. L-57-1560

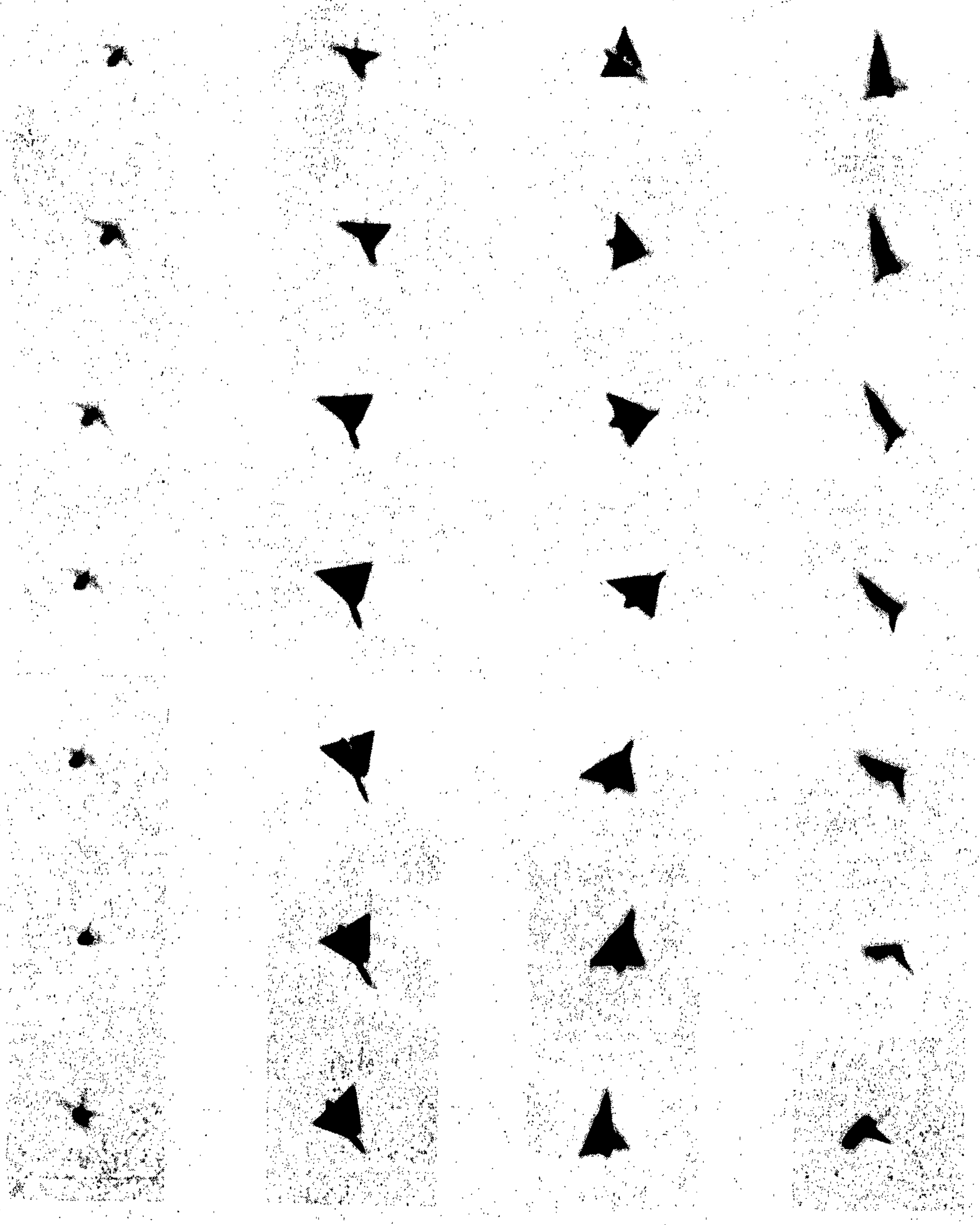


Figure 3.- Continued. L-57-1561

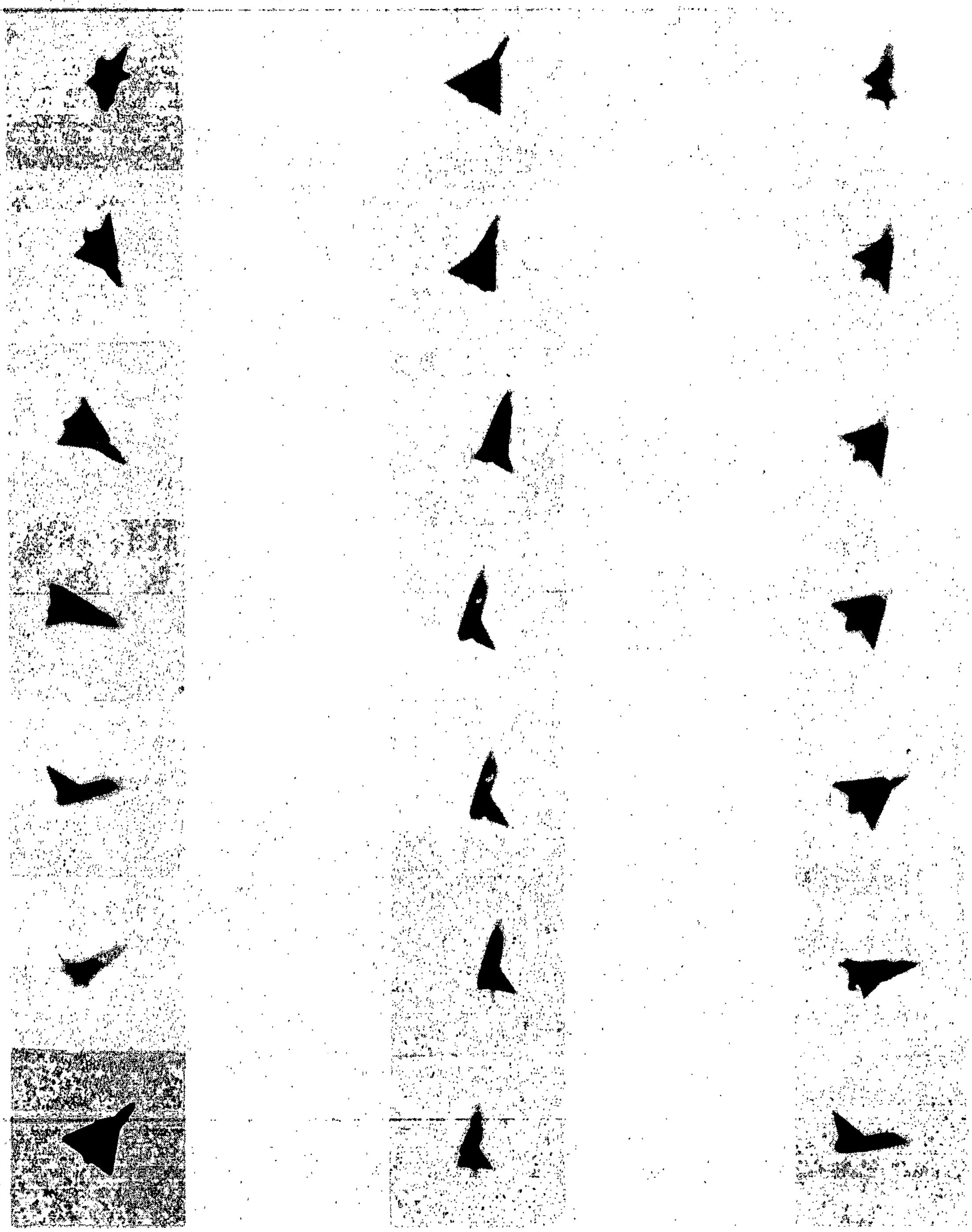


Figure 3.- Continued. L-57-1562

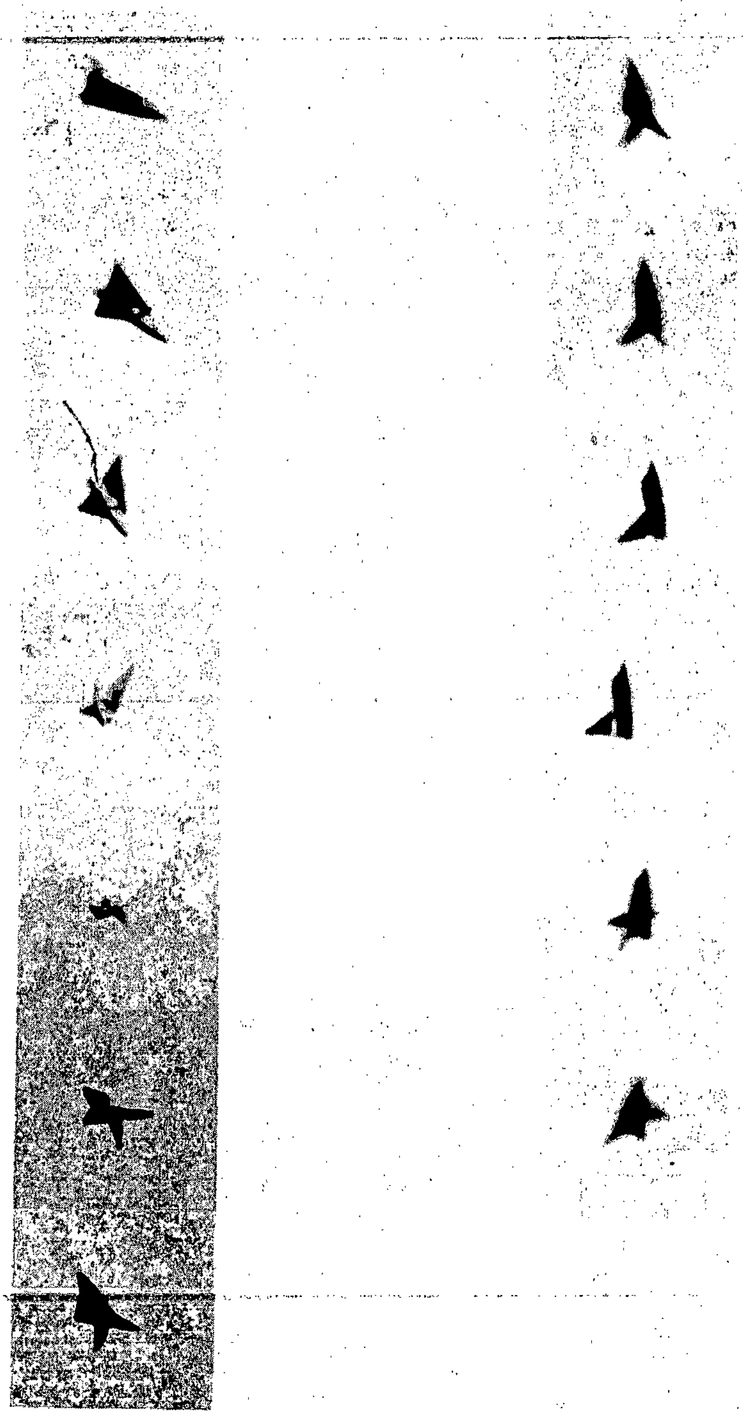
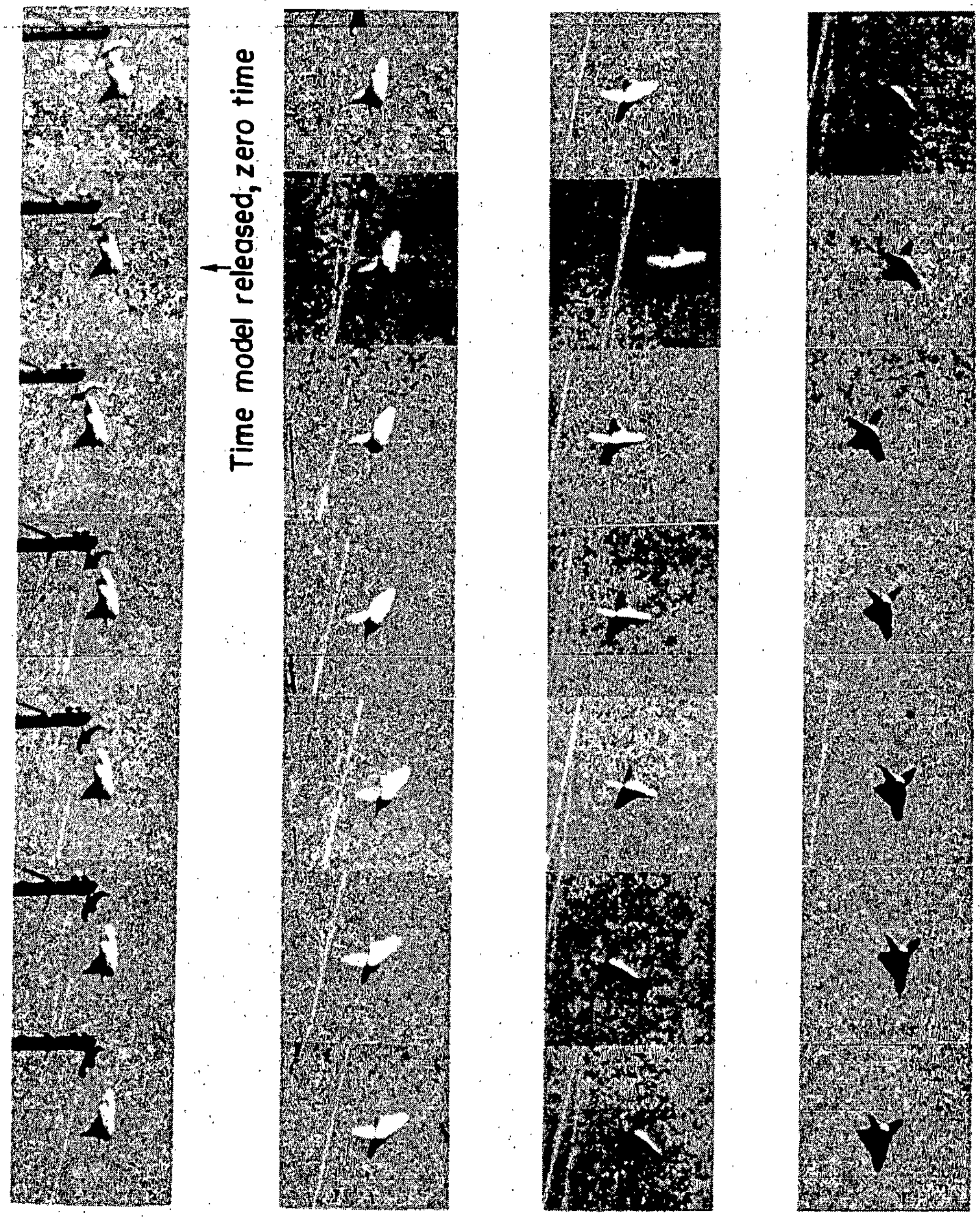


Figure 3.- Concluded. L-57-1563



L-57-1564

Figure 4.- Film showing motion of a 1/18-scale model of the Ryan X-13 airplane after being dropped from a hovering flight attitude. Film was taken at 64 frames per second. (Idle engine speed simulated with rotation of flywheel clockwise from rear.)

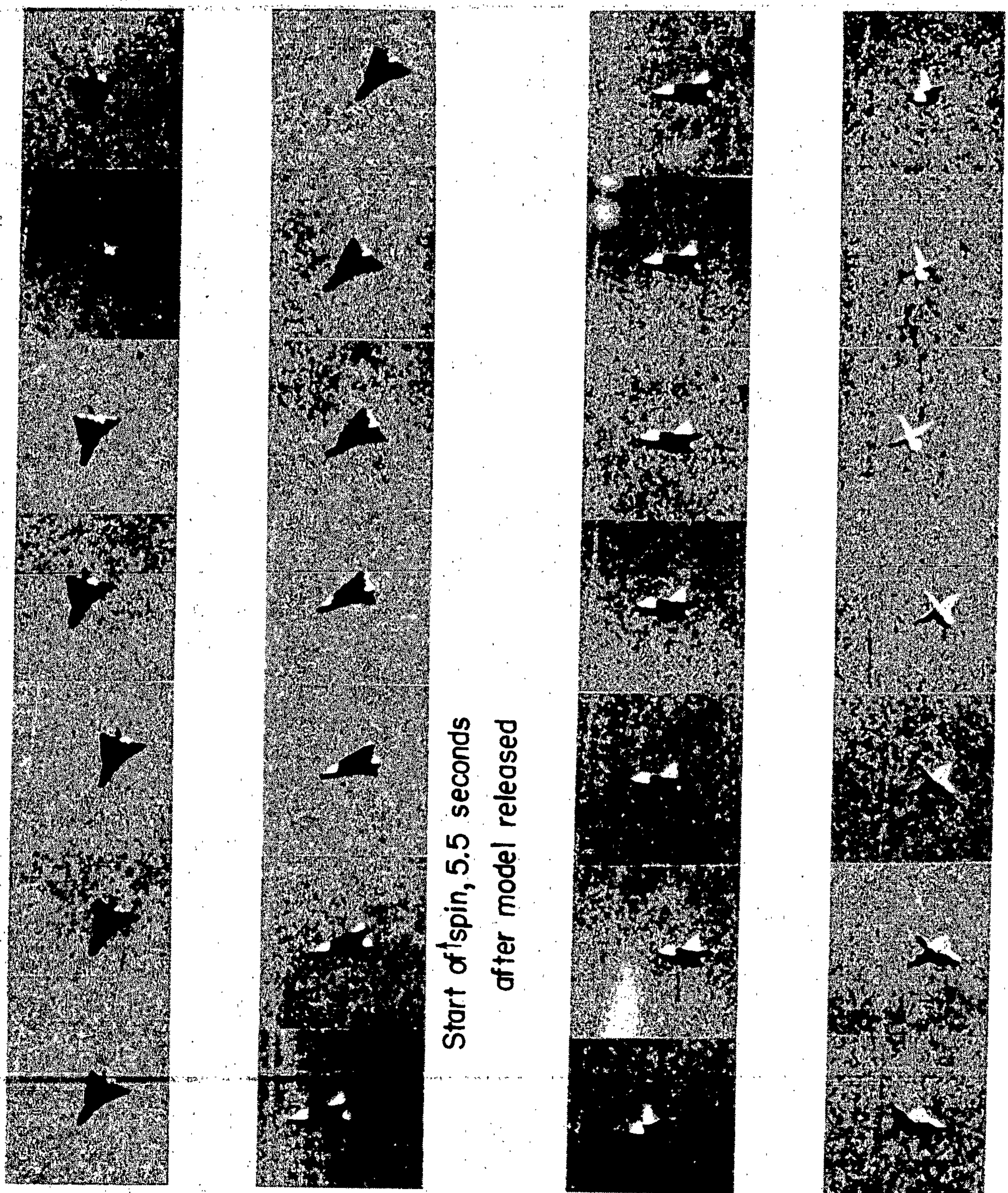


Figure 4.- Continued. L-57-1565

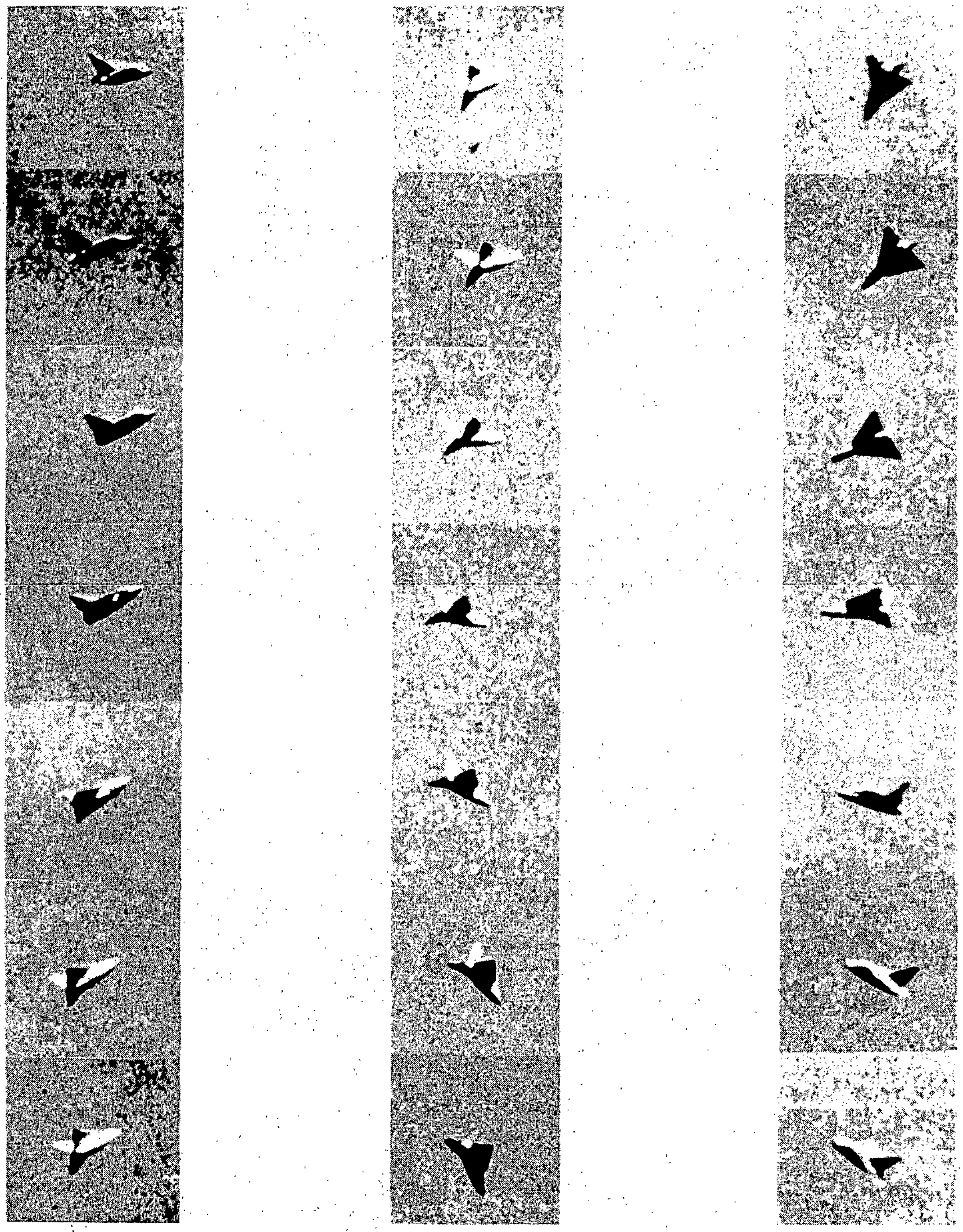


Figure 4.- Continued. L-57-1566

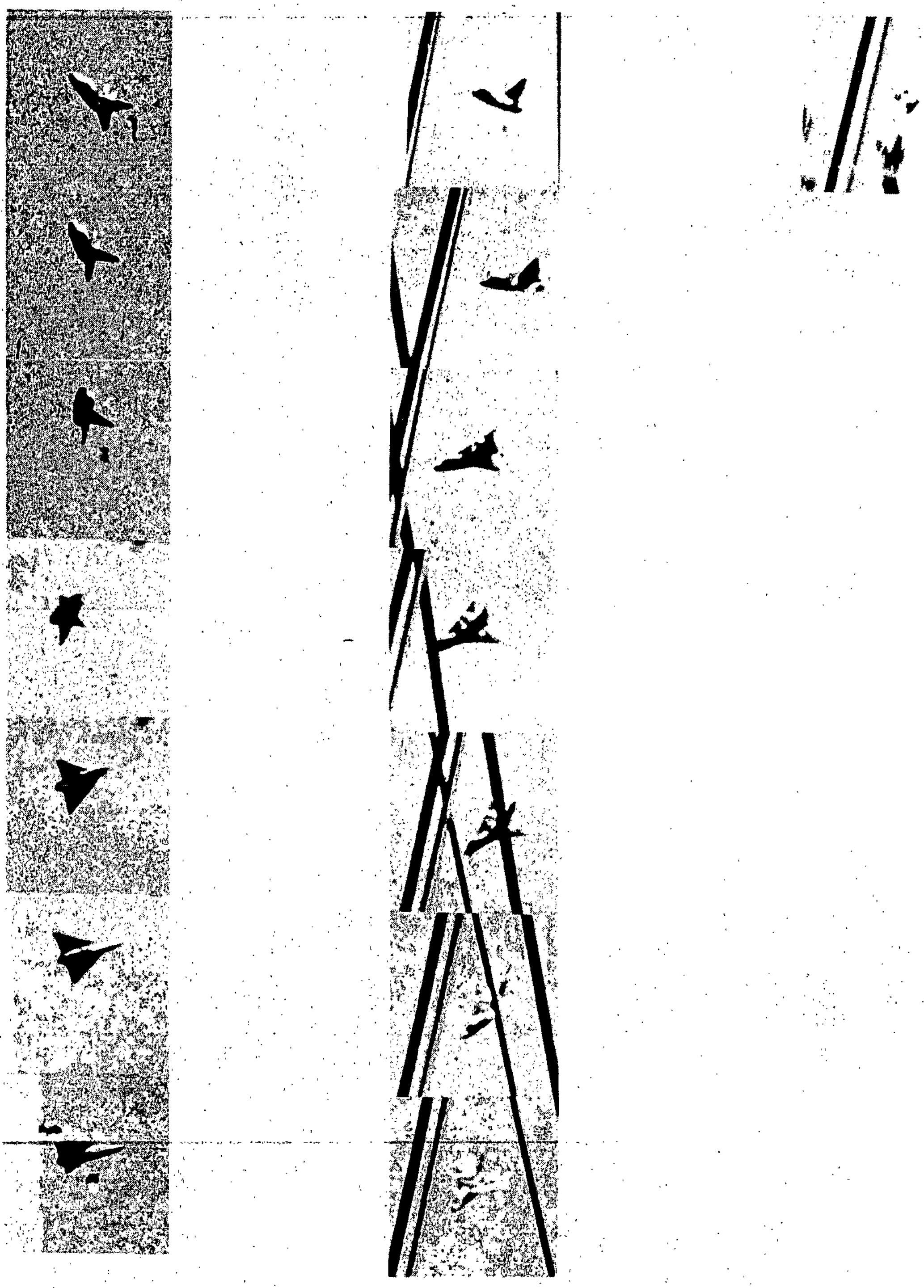


Figure 4.- Concluded. L-57-1567

[redacted]

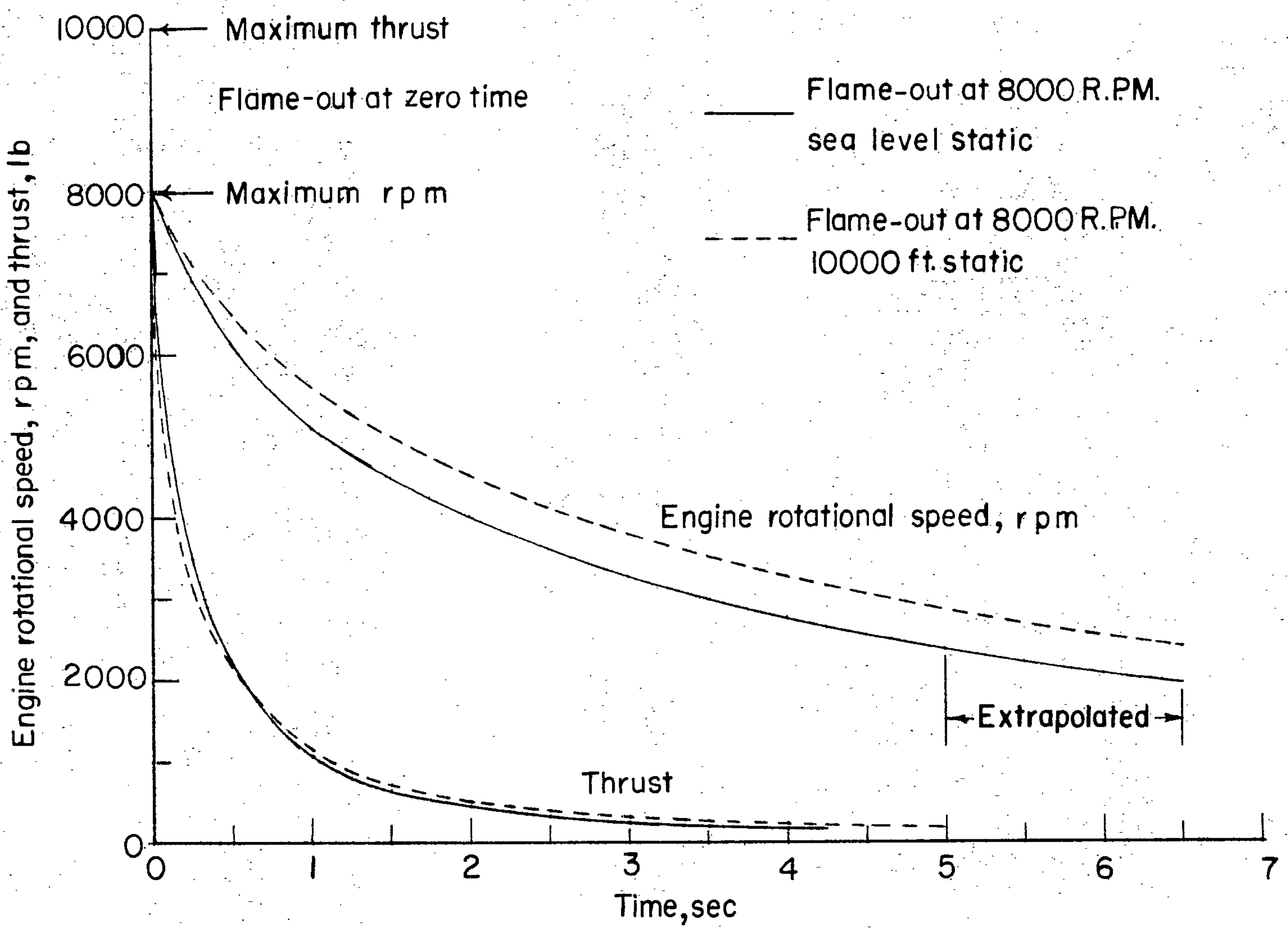


Figure 5.- Engine speed and thrust after flame-out for the Rolls Royce Avon R.A. 14 jet engine.

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CONCLUDING REPORT OF FREE-SPINNING, TUMBLING, AND RECOVERY CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE

COORD. NO. AF-199

By James S. Bowman, Jr.

ABSTRACT

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/18-scale model of the Ryan X-13 airplane to determine its spin, recovery, and tumbling characteristics and also to determine the minimum altitude from which a belly landing could be made in case of power failure in hovering flight. The gyroscopic moments of the simulated jet engine rotating parts had a large effect on the spinning characteristics. The model did not tumble in the ordinary sense (end-over-end pitching motion) but tended to enter a wild gyrating motion. The minimum altitude required for a belly landing was indicated to be about 4,200 feet.

INDEX HEADINGS

Airplanes - Specific Types	1.7.1.2
Spinning	1.8.3
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